§54. Energy Resolved Soft X-ray Imaging in a Long Pulse Discharge of LHD

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Soft X-ray imaging by a CCD (Charge Coupled Device) camera has recently been applied to the diagnostics of helical plasmas.[1] Although the photon energy range detected by the CCD can be controlled by choosing the thickness of a metallic filter, it is generally difficult to exchange the filters quickly within a short pulse single discharge. In LHD experiments, however, long pulse discharges under quasi steady state can be routinely sustained for several minutes by ion cyclotron resonance heating.[2] In this fiscal year we have developed and demonstrated a diagnostic system for energy resolved soft X-ray imaging in such long pulse discharges of LHD.

A frame transfer type soft X-ray CCD camera (Andor Technology, DO435-BV) is used as a detector. The other components of the system include a pinhole, a pneumatic mechanical shutter and a remotely rotatable filter disk with 8 beryllium (Be) filters. The thicknesses of the 8 filters are 50, 70, 100, 150, 250, 450, 850 and 1650 μm. The CCD camera has been installed in a tangential viewport of LHD. The CCD exposure to the plasma emission during the rotation of the filter disk can be avoided by adjusting carefully the timings of the shutter, the rotation of the filter disk and the readout of the CCD.

A two-dimensional image for a specific photon energy range can be obtained by taking the difference between two signals for adjacent filter thicknesses. Figure 1 shows theoretical transmission curves for the differences of the pairs of adjacent Be filter thicknesses. The peaks of these curves correspond to the typical photon energies obtained for each differential image.

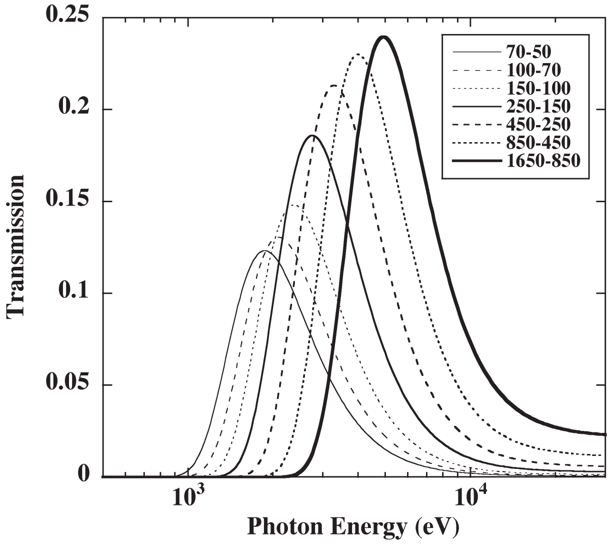

Fig. 1. Transmission curves for the differences of the pairs of Be filter thicknesses (in μm) used in this study.

A trial experiment has been carried out in a quasi-steady state long pulse discharge sustained by ion cyclotron resonance heating (ICRH). Figure 2 displays a contour for the two-dimensional tangential plasma image obtained from the difference between 850 and 450 μm filter thicknesses. The frame rate and the exposure time of the CCD were set to 10 and 5 seconds, respectively. The diameter of the pinhole was set at 0.1 mm, and 2×2 binning of the CCD pixels was performed to improve signal-to-noise ratio. The profile of Fig. 2 is clearly peaked rather than that obtained from the difference between 100 and 70 μm filter thicknesses (not shown). If the observed soft X-ray intensity were dominated by continuum emissions, this difference in profile would be due to the effect of the electron temperature profile. However, the data of a pulse height analyzer (PHA)[3] obtained in the same discharge shows prominent line spectra of K_α lines from iron, nickel and titanium. Therefore the measured profile seems to be affected by not only the electron temperature but also the profile of impurities. In the future, the measurement in a long pulse discharge by electron cyclotron resonance heating (ECRH) will be planned, in which the effect of impurity line emission would be weaker and two-dimensional mapping of electron temperature may be possible.

References

1) Liang, Y. et al.: Plasma Phys. Control. Fusion **44** (2002) 1383.

2) Kumazawa, R. et al.: Nucl. Fusion **46** (2006) S13.

3) Muto, S. et al.: Rev. Sci. Instrum. **72** (2001) 1206.

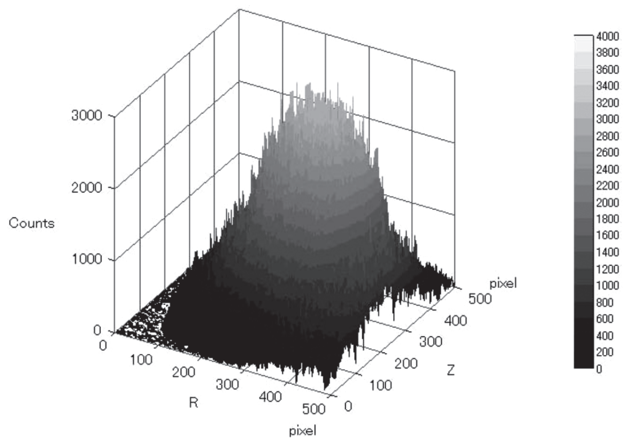

Fig. 2. The contour for a two-dimensional image obtained from the differential signal between 450 and 850 μm Be filter thicknesses.